Hot Mix Asphalt Production and Testing

Construction Inspector's Training Manual

January 2005

Washington State
Department of Transportation

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Introduction

Part 1 Introduction

Importance of Plant Inspection

Intelligent and adequate inspection at the asphalt plant will help insure the Agency is getting a quality product for the investment.

The "Asphalt Plant Inspector" performs a key role in the determination of a finished product in which our customers use.

Therefore, it is important that the inspector be knowledgeable on the workings of an asphalt plant and the effect that adjustments and maintenance of the plant can have on mix quality and consistency.

Importance of Testing

With the advent of Quality Assurance (QA) specifications the role of the plant inspector has evolved from one that was highly involved in the operation of the asphalt plant to one that is more involved in verification that the material produced by the Contractor is in conformance with the specifications.

Various testing procedures are available to the Inspector to ensure that the component materials and the completed mixture meet the requirements of the specifications.

Course Objectives

This course contains information to help you, the Inspector understand:

1. Plant Safety
2. How Hot Mix Asphalt (HMA) is produced.
3. Basic properties of HMA.
4. Mix design process.
5. Proper sampling and test methods.
6. Calculations of Volumetric Properties

Superpave

The Strategic Research Program (SHRP) was established by congress in 1987 as a five year, $150 million research program to improve the performance and durability of the United States roads and to make those roads safer for both motorists and the highway worker. $50 million of the SHRP research funds were used for development of performance based asphalt specifications to directly relate laboratory analysis with field performance.

Superpave (SUperior PERforming PAVEments) is a product of the SHRP asphalt research. The Superpave system incorporates performance based asphalt materials characterization with the design environmental conditions to improve performance by controlling rutting, low temperature cracking, and fatigue cracking. The three components of Superpave are the asphalt binder specification, mixture design analysis system, and a computer software system.

Superpave has two parts to the mix design system, the volumetric design and the performance prediction system. The following is a brief description of the volumetric mix design process:

WSDOT Superpave volumetric mix design is a structured approach consisting of the following steps:

Region Materials	Selection of mix class, grade of binder and design level
Contractor	Selection of aggregate source, binder and anti-strip suppliers Completes 3 trial blends to determine desired asphalt content Submits gradations and asphalt content for Job Mix Formula
HQ Mats-Lab	Verification of asphalt content and volumetric properties Evaluation of moisture susceptibility for stripping

Plant Safety

The asphalt plant is a very unique work environment with a high volume of traffic. Plant crews work long hours operating the plant during production and maintenance duties after production has ended. Fatigue can play an important role in most plant accidents.

As the inspector you should be considered part of this crew. A safe environment can only be achieved by the creation of teamwork.

Safety begins with having a complete knowledge of your work environment and the people that share it with you. So take the time to get to know your fellow workers. Ask the plant operator to give you a walk around tour and familiarize you with the plant layout.

Some points of concerns for safety are as follows:

Personal Safety Equipment

Wear your hard hat, hearing protection, safety glasses and protective clothing

Leather gloves are recommended when sampling HMA

Steel-toed boots are also recommended

Burns

Have a first aid kit that includes a burn kit. Know what to do if an asphalt burn occurs.

Sampling

Inspect the sampling platform or station provided by the contractor. It should provide an easy access, free from pinch points, unguarded belts or overhead hazards.

The platforms shall allow the sample to be taken without the Engineer entering the hauling vehicle.

Environment

Use proper lifting techniques when transporting samples.

Be aware of overhead hazards.

Be very cautious when you park your vehicle or walk in a traffic area.

Always be on the lookout for moving equipment and make eye contact with the driver before entering the area.

Duties of the Plant Inspector

Inspection During Mixing Operations

Throughout the day, the Inspector shall take the required samples of the HMA, mineral aggregates and liquid asphalt in accordance with the Quality Assurance program.

It is very important that the inspector observe and monitor the whole production process throughout the day and note any inconsistencies in your “Inspector’s Daily Report”.

Changes in asphalt content, moisture and over heating can quickly be detected by observing the appearance or color of the mix, additional samples can be taken to assure quality.

Temperature is a critical part in the production of HMA. Periodic checks of the mix temperature must be made to ensure uniform material is being produced. The Asphalt supplier will provide recommended mixing and compaction temperatures in the form of “Viscosity Curves”.

While maintaining an attitude of cooperation, courtesy and diplomacy with the Contractor, the Plant Inspector must insist that the requirements of the specifications be met. Notify the Contractor and Project Engineer of all test results in a timely manner.

Miscellaneous Duties

The Plant Inspector may supervise the work of the scale person on truck weighing scales at the plant, and shall see that the required tests of the scales are performed. The Inspector must see that tickets are properly made out and issued for each truckload of mixture delivered, and shall also see that daily totals are promptly obtained and entered on the daily report.

Before trucks are allowed to be loaded at the plant, a check shall be made to see that the truck beds are properly lubricated as required in the specifications. No pools of release agent shall be allowed to remain in the truck bed following this operation. The truck bed should be raised to allow any excess material to be drained off.

Upon completion of the project, the Contractor must be required to shape up any remaining aggregates into neat stockpiles, and remove all debris from the plant site, when the Contractor is occupying a site furnished by WSDOT.

Part 2
HMA Production

Part 2 Hot Mix Asphalt

Asphalt Plant Facilities

Inspectors assigned the testing and inspection duties of hot mix asphalt at the production facility should familiarize themselves with the basic operations of the plant and its components.

Checklists have been developed to raise the inspector's awareness in areas of concern. It is not required to follow a checklist, but may prove helpful to assure conformance to the specifications.

In this section, we will discuss the typical types of production facilities and common materials in use.

Stockpile

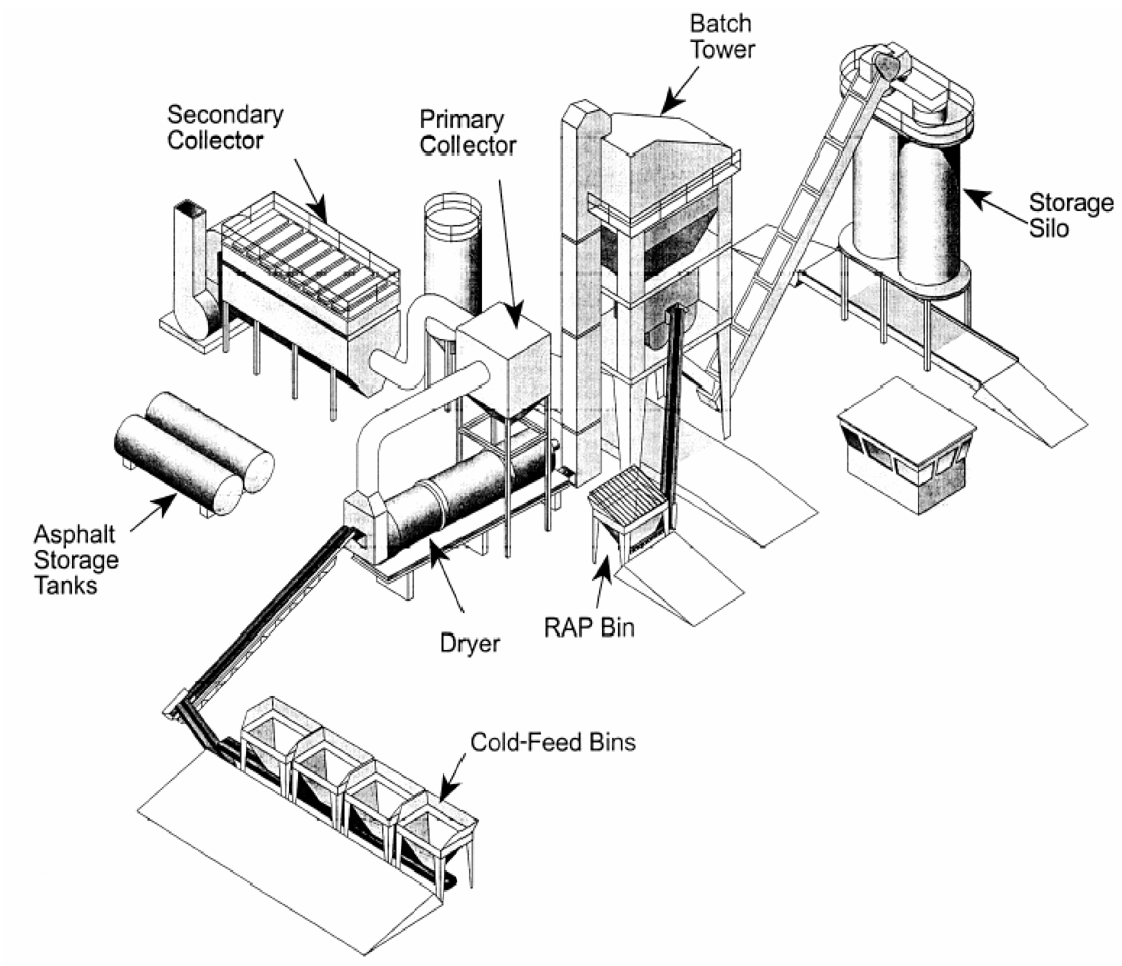
Stockpiles are to be constructed in a manner that will maintain the integrity of the processed material.

Great care is taken during the crushing process to assure the material will meet specifications. Improper handling of this material into or out of the stockpile will change the properties of the final product.

Types of plants

Batch Plant

A batch plant produces hot mix asphalt in 3 to 5 ton batches using a mixing device called a "Pugmill". These batches are then accumulated in storage silo for transport to the paving project.



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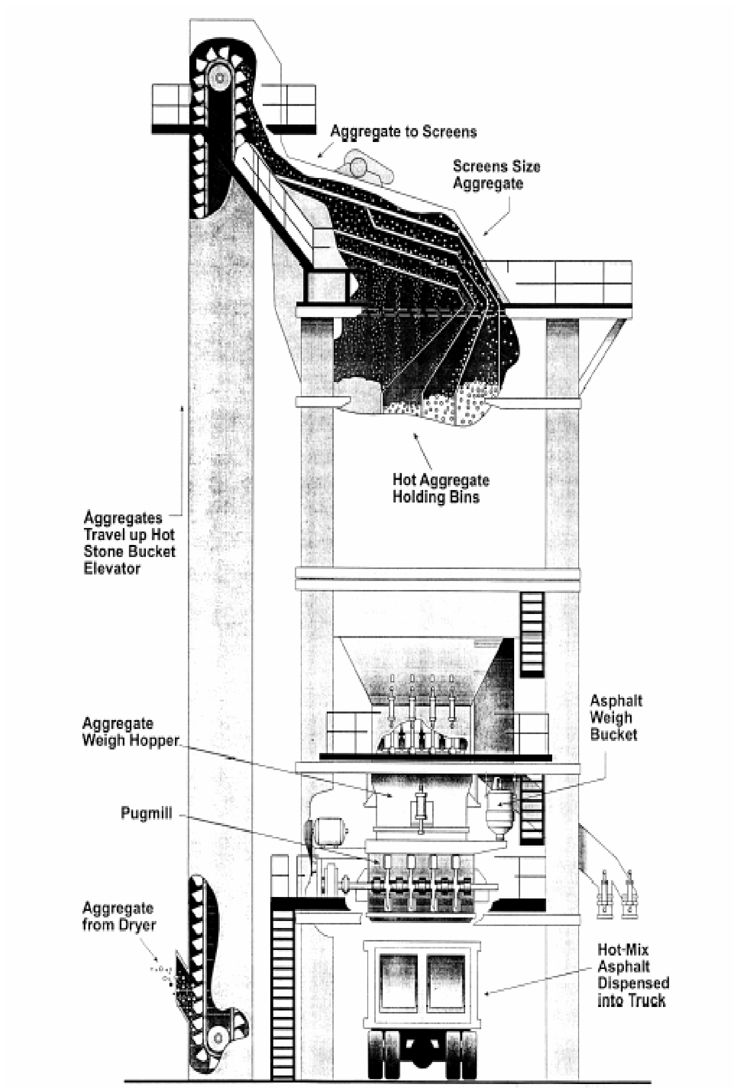
Batch Plant

Batching Tower

The batching tower divides the hot dry aggregate into fractions, dependant of their size. Each size of aggregate resides in its own bin. This lets the plant operator change the gradation of each batch produced.



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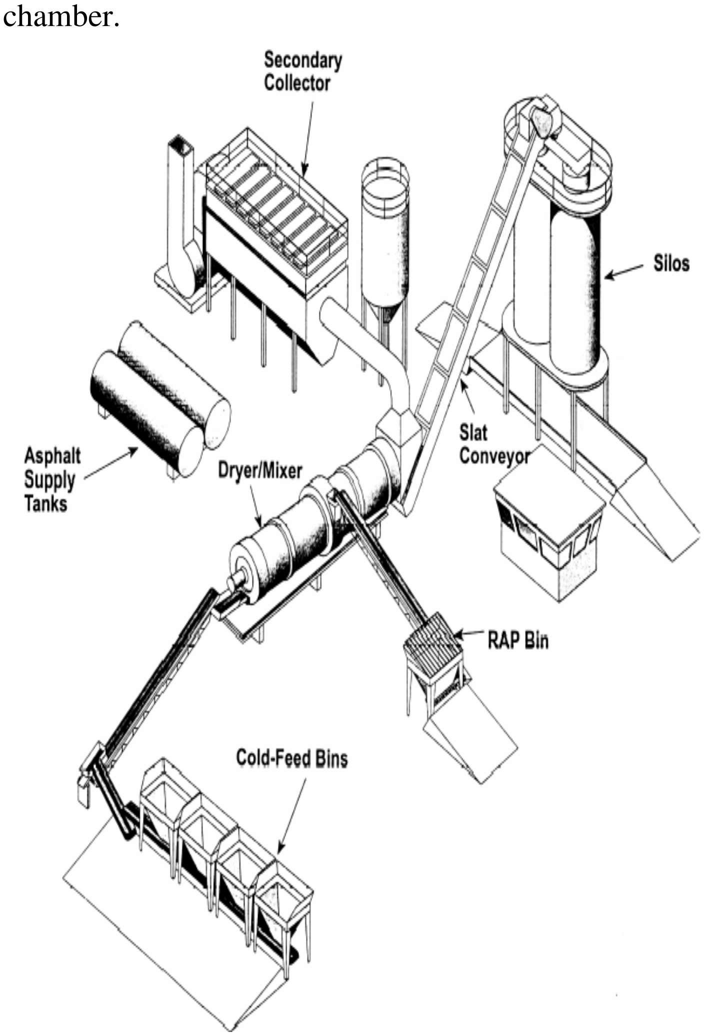
Drum Mix Plant

Drum mix plants are placed in two categories, which describes the direction in which the aggregate travels through the drum.

In a Parallel-Flow drum mix plant the aggregate enters at the flame end and travels from the drying zone to the mixing zone.

A Counter-Flow drum moves the aggregate towards the flame for drying and reverses direction for the mixing process in the outer chamber.



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Cold Feed Bins

Proportioning of the aggregates begin with the cold feed bins. The plant is equipped with multiple bins to handle different sizes of new aggregates. A bulkhead or divider should be used between each bin to prevent overflow of one aggregate into an adjacent bin. Contamination of different size aggregates can significantly alter the gradation of the mix being produced.

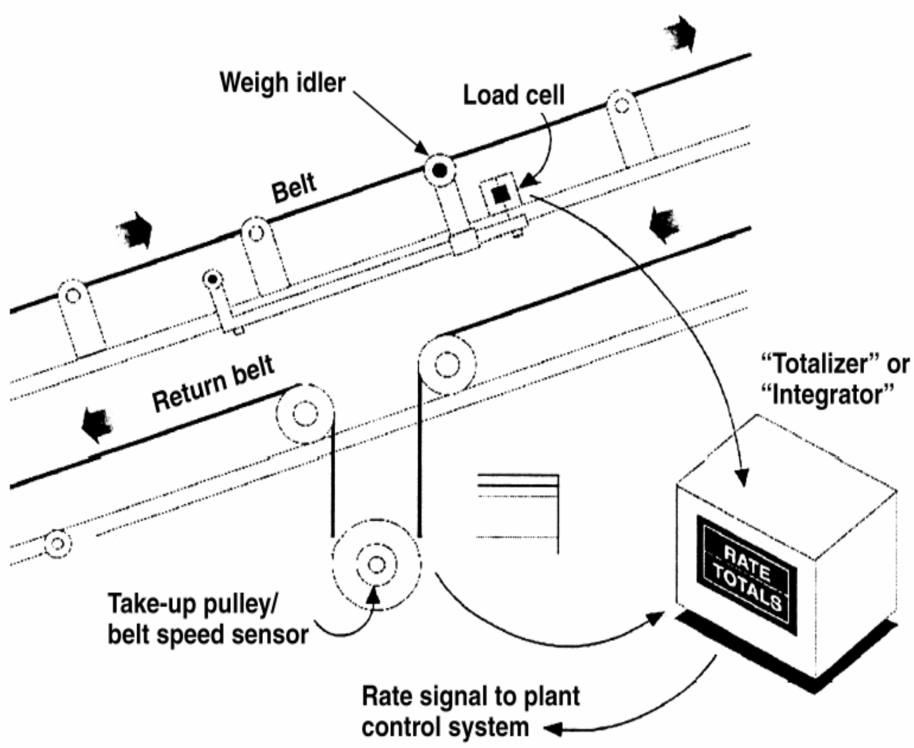
Some cold feed bins are equipped with a gate to control the size of the discharge opening. This will set the amount of the material used from that bin.

Others have variable-speed belt conveyors which deliver the material from the bin. The speed of the belt can be used to control the amount of material to be used. The speed setting for each individual belt feeder is adjusted independently to allow the proper amount of aggregate to be pulled from each particular bin.

This proportioning is more important to the drum type plants than to a batch plant.

Belt Scales

Material is loaded on a belt from the Cold Feed Bins. The belt is ran at a specified speed. A computer calculates the tons of aggregate transported to the dryer by the accumulated weight over the load cell.



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Dust Collector

All batch and drum mix plants have a small amount of fine aggregate and dust created from the drying process. In order to meet federal and state air quality codes, emission control equipment is necessary to capture particulate emissions that might otherwise be released into the atmosphere. In addition, some emission control devices permit the plant operator to collect and return fines back into the mixture.

The fans from the dust collectors create a draft which aid the blower in the combustion of the burner fuel.

There are three common types of dust collectors:

Primary
The primary dust collector is located at the end of the dryer unit. It uses a cyclone effect to collect the larger dust particles and fine aggregate from the exhaust gases. The remaining particles will be filtered by either a Wet Scrubber or Baghouse.

Wet Scrubber
The exhaust from the primary collector is forced through a venturi type narrow opening and sprayed with a fine mist of water. The heavy particles fall out and are collected into a settling pond. The remaining hot gases are released into the atmosphere.

Baghouse
The exhaust gases that pass through the primary collector are pulled by the exhaust fan through the fabric filters in the baghouse. With the use of a baghouse, fines can be reclaimed and returned to the mixing unit. This can be accomplished by incorporating a surge hopper for storage of fines to be used or fed directly back to the drum/mixer. The remaining fines will be disposed of by use of a settling pond or other appropriate means.

Liquid Asphalt Storage

Asphalt storage tanks shall be insulated and heated to maintain the proper temperature specified by the supplier.

The most common method of heating the liquid asphalt is by transfer oil. This type of heating reduces the chances of damage to the paving grade asphalt by overheating.

Transfer oil is a light petroleum product that is heated in a coil heater by use of a propane or diesel burner. It is then piped into coils of the asphalt cement storage tank.

The coils of the asphalt storage tank are located in the bottom of the tank. The heated liquid asphalt rises, which creates a circulation effect. This along with a pump to aid in the circulation, can maintain the proper temperature.

A lesser used method for heating of the asphalt storage tank is "direct fired". This is where combustion from the burner is the direct source of heat. This method is unacceptable according to our Standard Specifications.

All supply lines for the liquid asphalt and heating oil should be insulated to prevent heat loss and provide safety for plant personnel.

The lines used to fill the tank from the transport truck and the discharge line to the plant should be located near the bottom of the tank.

"Dipping" or "sticking" the tank is used to measure the empty portion of the tank, from the top, down to the level of liquid.

The plant operator should know the capacity of the storage tank and have charts used for calculating the volume of asphalt cement in the tank.

Storage Silo

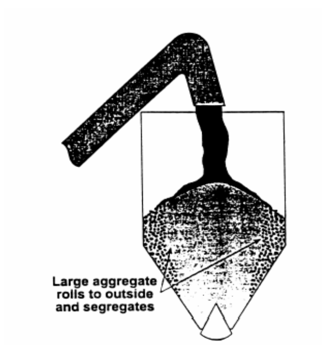
The main purpose of the silo is to hold the mix temporarily until the next transport vehicle is available. Some silos are insulated and mix can be held for longer periods. Standard Specifications allow the mix to be held in the silo for no more than 24 hours.

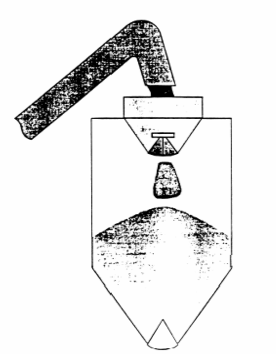
A variety of transport devices are used to carry the hot-mix asphalt from the discharge chute on the drum mixer or from the weigh hopper under the pugmill of a batch plant to the silo. The most popular equipment is the drag slat conveyor.

Segregation is of most concern when the hot-mix is deposited from the conveyor into the silo.

Segregation can occur when the material is allowed to drop into a conical pile at the center of the silo. The coarse aggregate rolls down and collects at the bottom of the pile creating rock pockets. Also if the material is thrown into the opposing wall of the silo by the conveyor, the coarser pieces will run to the opposite side and segregate.

Segregation can be reduced with the use of a “Gob hopper” or batcher. The hopper is located at the top of the silo. It collects 1-2 tons of mix and deposits the mix as a mass. When the mass hits the bottom it splatters in all directions uniformly.





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Part 3

Basic Properties of Hot Mix Asphalt

Part 3 Basic Properties of Hot Mix Asphalt

Basic Properties of Hot Mix Asphalt (HMA)

There are three major components to HMA, mineral aggregate, asphalt cement and air.

Additives are also incorporated into the HMA to achieve desired results.

In this chapter we will be going over all of the different components that make up the asphalt paving mixture.

Asphalt

Asphalt is a dark brown to black cementitious material in which the predominating constituent are bitumen's, which occur naturally or are obtained in petroleum processing. The refining process, heats crude petroleum in stages and removes different petroleum products. The residue from the refining process is known as asphalt. The asphalt from different crude sources can be blended together to meet specifications as needed for different paving grade asphalt cement.

Several standard grading systems have been used to label paving asphalts, these include:

Penetration	(Pen)
Viscosity	(AC)
Aged Residue	(AR)
Performance Base Asphalt	(PBA)

And now we have "Performance Grade" (PG)

PG Grades

PG 58-22 is used in Western Washington where the ambient temperatures are mild during both the winter and summer months.

PG 64-28 is used in Eastern Washington where the ambient temperatures are very hot during the summer months and moderately cold during the winter months.

PG 70-28 is used in high traffic loading areas, such as intersections and ramps.

Mineral Aggregates

The aggregates make up 90 to 95 percent of the total asphalt concrete paving mixture, they form the “skeleton” or structure. The aggregate is primarily responsible for the load supporting capacity of the pavement.

Blending Sand

Blending sand is a clean, hard sound material, naturally occurring sand or crushed fines that is added to the crushed aggregate to make up deficiencies of the material passing the No. 40 sieve that has occurred during the crushing process**.**

Additives

Mineral Fillers

Mineral Filler is a finely divided mineral product with at least 70 percent of which will pass the No. 200 sieve. Pulverized limestone is the most commonly manufactured filler, although other stone dust, hydrated lime, Portland cement, and certain natural deposits are also used.

Anti-strip Additives

Chemicals are used to promote adhesion and bonding of the asphalt to the aggregates. Liquid additives are typically added to the asphalt cement, but other products such as Lime or Polymers can be applied to the aggregates.

Recycled Asphalt Pavement

Asphalt pavements that have fatigued or out lived their life cycles may be reclaimed and introduced into the pavement being placed. Recycled Asphalt Pavement (RAP) can be an economical benefit to both the Contractor and Agency.

If RAP is added to the HMA being produced the Contractor is responsible for meeting the specifications listed in the contract.

Mixture

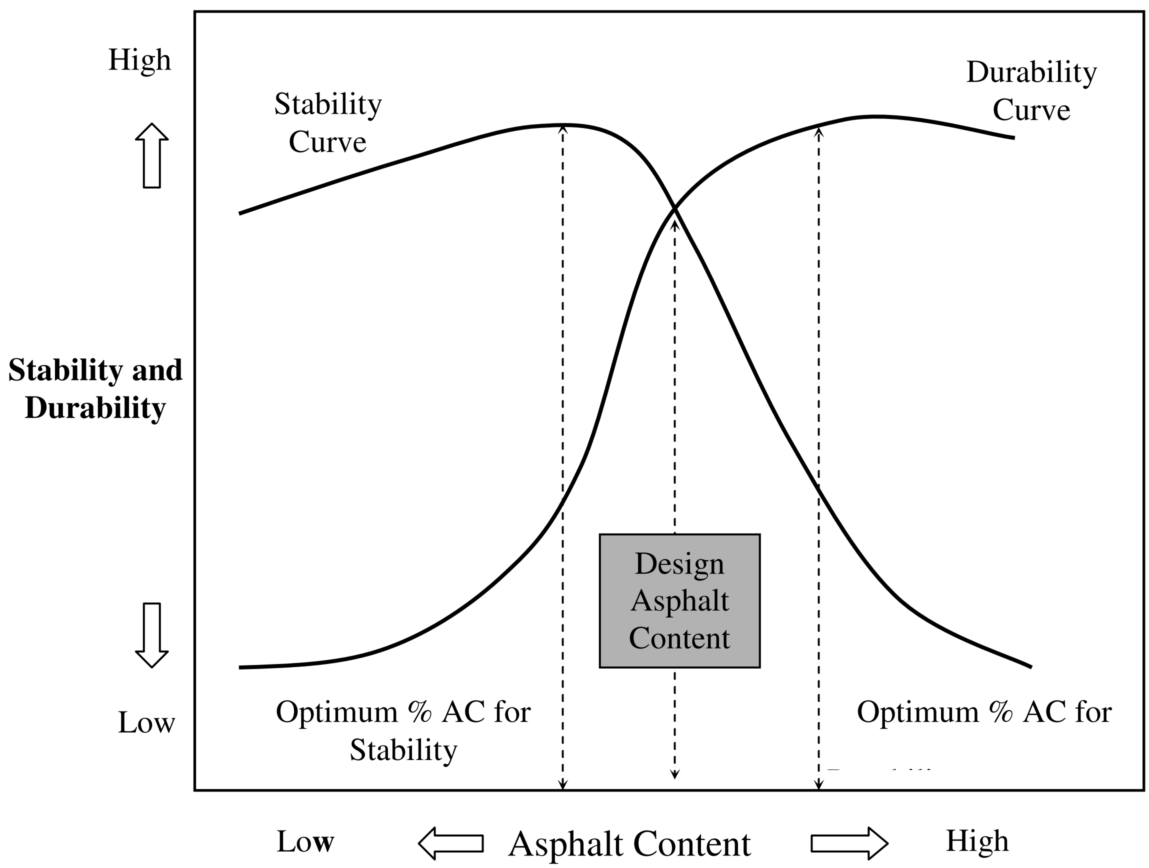
Gradation is the most important property of HMA, it affects all aspects of the mixture.

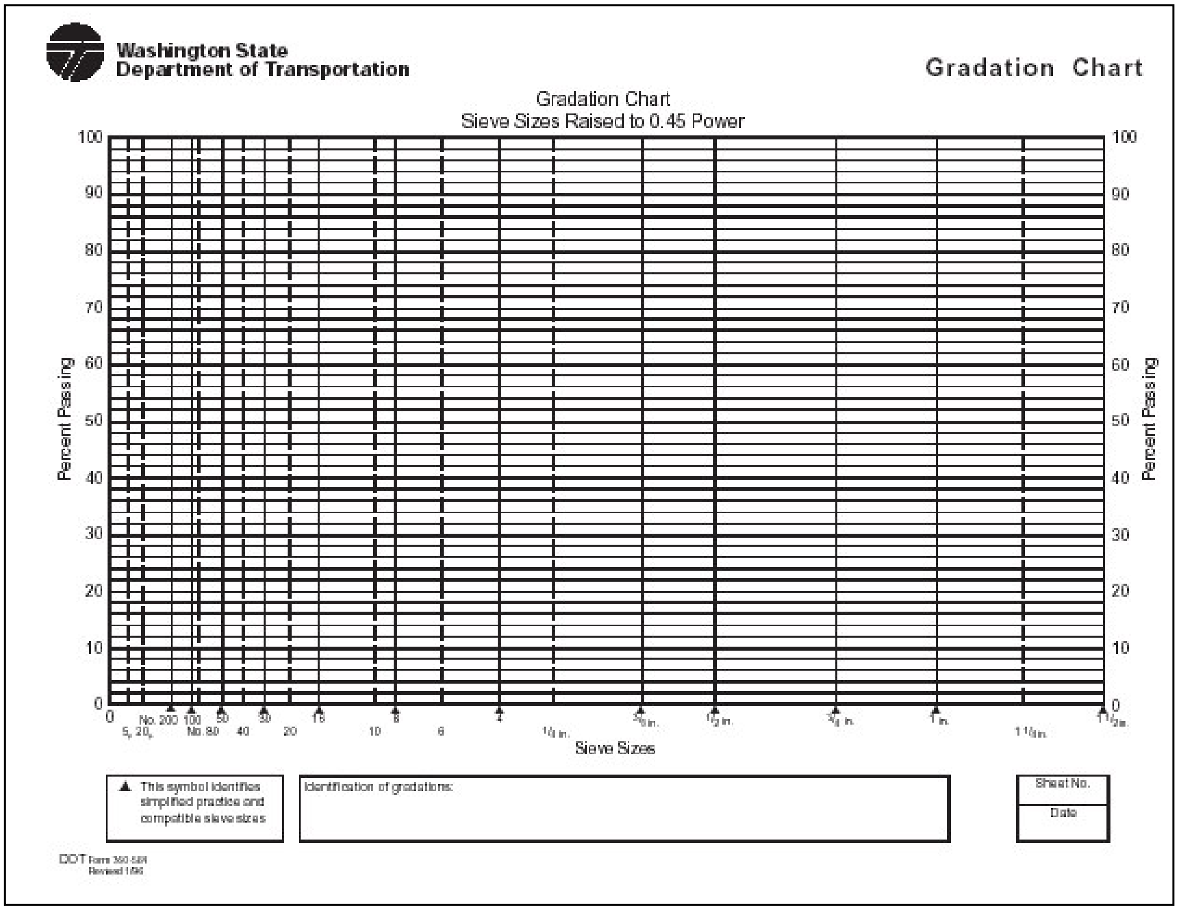
When proportioning the aggregates into different sizes, the contracting agency can specify what type of pavement surface texture and internal structure they desire.

There are three major types of asphalt pavement used today,

Dense Graded
Open Graded
Gap Graded

The industry standard is to use the 0.45 power chart for determination of the aggregate structure. It can be used to indicate stability, durability and constructability. A tightly packed aggregate structure leaves no room for the asphalt cement.




Washington State
Department of Transportation
Gradation Chart
Gradation Chart
Sieve Sizes Raised to 0.45 Power
Percent Passing
100
90
80
70
60
50
40
30
20
10
0
No. 200
100
50
30
16
8
4
3/8 in.
1/2 in.
3/4 in.
1 in.
1 1/2 in.
No. 80
40
20
10
6
1/4 in.
1 1/4 in.
Sieve Sizes
This symbol identifies simplified practice and compatible sieve sizes
Identification of gradations:
Sheet No.
Date
DOT

Exercise 1: Using a straight edge and the 0.45 Chart in the back of your book

1. On the 0.45 Power Chart draw a line from the 3/4" @ 100% to 0 (zero)
2. Find the "Restricted Zone" on the Max. Density Line in SS 9-03.8(6)
3. Now plot the specifications given below for the 1/2" Superpave mix.
4. Connect the "Upper Limit" points
5. Connect the "Lower Limit" points

Sieve Size	Lower Limit	Upper Limit
3/4"		**100**
1/2"	**90**	**100**
3/8"		**90 max.**
No. 8	**28**	**58**
No. 200	**2.0**	**7.0**

Part 4

Mix Design

Part 4 Mix Design

Selection of Materials

In the selection of materials, there are several factors that have to be considered, the climatic conditions, (pavement temperatures), traffic speed and traffic loading conditions, as well as design life of the pavement expressed in ESAL's, and the location within the pavement structure. There are 7 different levels of traffic volumes from very low traffic to very high traffic. The 7 levels are used for the selection of materials, as well as for compacting the samples.

Binder

The proper Performance Grades (PG) of asphalt cement are based on two factors, traffic and pavement temperatures. Adjustments are made to the PG grade of asphalt cement based on traffic conditions and traffic volumes, which is extended to enhance the design life of the pavement. The PG grading system is defined by two numbers, which represent pavement temperatures. The first number PG 58-XX represents the high pavement temperature in degrees Celsius, while the second number PG XX-22 represents the low pavement temperature. All adjustments to the PG grading system are made in six (6) degree increments. The high temperature relates to the effects of rutting and the low temperature relates to cold temperature and fatigue cracking.

Determining the Pavement Design Life

The pavement design life is determined by calculating the expected ESAL's over a 15-year period.

Adjusting for Traffic Conditions

There will need to be consideration for making adjustments to the PG grade of asphalt cement for the different traffic conditions. The recommendation is to increase the high temperature by one grade for slow moving traffic (PG 58-XX to PG 64-XX) and standing traffic areas increase by two grades.

Adjusting for Mountain Areas

When determining the grade of PG asphalt cement to be used in the mountain areas, consideration should be given to pick one of the three base grades that best fits the conditions of the roadway that is to be paved. In most cases we should be using a PG 58-34 grade of asphalt cement for all mountain passes. The reason for this is due to the extremely cold winter months and the mild summer months.

Aggregate

The aggregate tests are divided into two parts, there are four consensus aggregate tests that control the aggregate during production, and the three source aggregate tests (which Washington State has modified by adding one test and eliminating two tests) that are intended to evaluate the quality of the aggregate from the source. All of these tests have different specifications, which are based on both traffic conditions and the location within the pavement structure.

The two source tests that Washington State has adopted are the Los Angles Abrasion test (which we currently use) and our current Washington State Degradation Test. The LA Abrasion test measures the toughness of the aggregate by estimating the resistance of course aggregate to abrasion and mechanical degradation during handling, construction, and in-service. The

Washington State Degradation test is used to measure the toughness and abrasion of the aggregate in the presence of water.

There were two other test that we have decided not to use, the Sulfate Soundness Test and the Deleterious Materials test.

The four aggregate tests that control the aggregate during production are; the course fracture, fine aggregate angularity (or fine fracture), flat and elongated particle shape test, and the sand equivalent test. Two new tests developed and incorporated into the Superpave system are, the fine aggregate angularity test (fine fracture) and a flat and elongated shape test.

The fine fracture test ensures a high degree of fine aggregate internal friction and rutting resistance. It is defined as the percent air voids present in loosely compacted aggregate smaller than the No.8. Higher void content means more fractured faces. The Flat and Elongated Particle Shape Test characterizes the percentage by mass of course aggregate that have a maximum to minimum dimension ratio greater than five. Flat and elongated particles are undesirable because they have a tendency to break during construction and under traffic.

Gradation

There are five asphalt mixture types that are specified in Superpave according to nominal maximum aggregate size: 3/8”, 1/2”, 3/4”, 1”, and 1 1/4. For aggregate, the nominal maximum size, (NMS) is the largest standard sieve opening listed in the applicable specification, upon which any material is permitted to be retained.

The Superpave gradation is based around four elements: the 0.45 power gradation chart, control points, a maximum density line, and a restricted zone.

Restricted Zone

The restricted zone resides along the maximum density line between the No. 8 sieve and the No. 50 sieve. Gradations that pass through the restricted zone have been called "a hump gradation" because of their characteristic hump shape in this area. In most cases, a humped gradation indicates an over-sanded or excessive amount of fines in the mixture. This gradation often results in a mixture that poses compaction problems during construction and offers reduced resistance to permanent deformation during its pavement life.

WSDOT research has shown that gradations cannot cross the maximum density line within the restricted zone. This is based on in service roadways that have shown severe rutting.

Selection of Design Aggregate Structure

Once binder and aggregate materials have been selected, various combinations of these materials are evaluated using the Superpave gyratory compactor. Three, and sometimes more, trial blends are evaluated. For example, assume that four aggregate stockpiles have been selected for use. The following table shows possible blend percentages for each of three trial blends.

Blend Percentages

Stockpile	Trial Blend 1	Trial Blend 2	Trial Blend 3
Coarse Aggr 1	20	30	40
Course Aggr 2	50	40	30
Manufactured Sand	20	15	20
Natural Sand	10	15	10
Total	100	100	100

Once the trial blends are established using the 0.45 power chart, a trial asphalt binder content is selected for each blend. The trial asphalt binder content is selected using an estimation procedure contained in Superpave or on the basis of the designer's experience.

Two specimens of each trial blend are mixed and compacted in the Superpave gyratory compactor. In addition, two loose specimens of each trial blend are produced and used to measure maximum theoretical specific gravity (rice density). The volumetric and identification characteristics of the trial blends are analyzed at 4 percent voids and compared with Superpave mix design criteria. Any trial blend that meets these criteria can be selected as the design aggregate structure.

Selection of Design Asphalt Binder Content

The next step involves selection of the design asphalt binder content for the design aggregate structure. This step is necessary to verify the approximate binder content used in the preceding step. The Superpave gyratory compactor is used to fabricate test specimens composed of the selected design aggregate structure, but at three different asphalt contents. The asphalt content that results in 4 percent air voids at the design number of gyrations is the design asphalt binder content. The design aggregate structure containing the design asphalt binder content becomes the design asphalt mixture.

Evaluation of Moisture Susceptibility

This final step requires that the design asphalt mixture be evaluated for moisture susceptibility. The Superpave system recommends using a test procedure called, AASHTO T283, "Resistance of Compacted Bituminous Mixture to Moisture Induced Damage." Washington State has elected to use our current "Modified Lottman" procedure at this time. We compact 6 specimens at different percents of anti-strip additive and moisture condition five of them. The moisture-conditioned samples are evaluated for their indirect tensile strength. The ratio of conditioned to unconditioned tensile strength is called tensile strength ratio or TSR. The design asphalt mixture is judged to be non-moisture susceptible if it has a TSR greater than 80 percent.

Job Mix Formula

The Job Mix Formula (JMF) is the "recipe" for combining the components of the mixture. It is the Contractor's responsibility to produce the HMA in accordance with the submitted JMF. The Project Engineer may approve the written request to adjust the JMF if the changes produce material of equal or better quality.

A change or adjustment approved by the Project Engineer for any constituent i.e., gradation or asphalt content, constitutes a new JMF.

New Job Mix Formula

Exercise 2

Plot the JMF on the 0.45 Chart previously used in Part 3.

The Contractor has requested to change the original Job Mix Formula (JMF) to the following gradation for their 1/2" Superpave. Using the 0.45 Power Chart plot the proposed gradation to verify the contractor has not gone into the restricted zone.

Proposed JMF

Sieve	% Passing
3/4"	100
1/2"	96
3/8"	88
#4	52
#8	35
#16	22
#30	17
#50	12
#100	9
#200	6.0

Part 5

Quality Assurance/ Quality Control

Part 5 Quality Assurance/Quality Control

Basis for Acceptance

Acceptance of HMA shall be as provided under Statistical, Nonstatistical and Commercial evaluations. Determination of Statistical or Nonstatistical acceptance shall be based on proposal quantities and shall consider the total of all bid items involving mix of a specific class.

Statistical Evaluation

Sampling and testing for Statistical evaluation shall be performed on a random basis at the frequency of one sample per sublot. The initial sublot size shall be determined from proposal quantities to provide not less than five uniform-sized sublots to comprise the project quantity with the initial JMF. The maximum sublot size shall be 800 tons.

Nonstatistical Evaluation

Sampling and testing for Nonstatistical evaluation shall be performed on a random basis. The sublot size shall be determined to the nearest 100 tons to provide not less than three uniform sized sublots, based on proposal quantities, with a maximum sublot size of 800 tons.

Commercial HMA Evaluation

The contractor shall submit a certified mix design. Verification of the mix design by the contracting agency is not required. The Project Engineer will determine anti-strip requirements for the HMA.

Commercial evaluations will be used for Commercial HMA and for other classes of HMA in the following applications: sidewalks, road approaches, ditches, slopes, paths, trails, gores, prelevel, digouts, and other nonstructural applications as approved by the Project Engineer.

Job Mix Formula Tolerances

After the JMF is determined the constituents of the mixture at the time of acceptance shall conform to the following tolerances listed in 9-03.8(7) or Special Provisions.

Exercise 3: Using the Ignition Furnace worksheet found in the back of the book, Std Specifications 9-03.8(6) and the Mix Design Report below:

1. Fill in the Sieve Sizes, JMF (Combined) and Specifications
2. Calculate the JMF Tolerances using SS 9-03.8(7) for Stastistical

Washington State Department of Transportation - Materials Laboratory
PO Box 47365 Olympia / 1655 S 2nd Ave. Tumwater / WA 98504
BITUMINOUS SECTION TEST REPORT

TEST OF: A.C.P. JOB MIX DESIGN SUPERPAVE CLASS 1/2"
DATE SAMPLED: 7/11/01
DATE RECVD HQS: 7/11/01
SR NO: 508
SECTION: SR5 TO SR7

WORK ORDER NO: 006020
LAB ID NO: 0000195459
TRANSMITTAL NO: 195459
MIX ID NO: G10006

---------CONTRACTOR'S PROPOSAL---------

Mat'l	3/4"- 1/2"	3/8"-#4	1/4"-0	COMBINED
Source:	L-23	L-23	L-284	
Ratio:	15%	26%	59%	
1"	100.0	100.0	100.0	100
3/4"	100.0	100.0	100.0	100
1/2"	50.1	100.0	100.0	93
3/8"	10.0	89.1	100.0	84
#4	0.0	12.3	93.8	59
#8	0.0	3.4	64.1	39
#16	0.0	3.0	39.5	24
#30	0.0	2.8	25.1	16
#50	0.0	2.7	18.0	11
#100	0.0	2.4	12.7	8
#200	0.5	2.3	8.9	6.0

---------LABORATORY ANALYSIS---------SPECIFICATIONS--

ASPH % BY TOTAL WT OF MIX:	7.0	7.4	7.5	
%Gmm @ Ninit: 8	84.6	85.6	85.9	≤ 89.0%
% VOIDS @ Ndes:100	5.6	4.4	4.1	4.5%
% VMA @ Ndes: 100	16.1	15.9	15.9	≥ 14.0%
% VFA @ Ndes: 100	66	73	75	65 - 75
DUST / ASPHALT RATIO	1.2	1.1	1.1	0.6 - 1.6
Pbe- PERCENT BINDER EFFECTIVE	5.1	5.6	5.7	
Gmm - MAX S. G. FROM RICE	2.333	2.318	2.314	
Gmb - BULK S. G. OF MIX	2.202	2.216	2.220	
Gsb - OF AGGREGATE BLEND		2.441		
Gsb - OF FINE AGGREGATE		2.479		
Gb - SPECIFIC GRAVITY OF BINDER		1.040		

---------LOTTMAN STRIPPING EVALUATION---------

	0%	1/4%	1/2%	3/4%	1%
Visual Appearance:	NONE	NONE	NONE	NONE	NONE
% Retained Strength:	78	85	98	92	96

---------RECOMMENDATIONS---------

SUPPLIER	ALBINA
GRADE	PG64-22
% ASPHALT (BY TOTAL MIX)	7.4
% ANTI STRIP (BY WT ASPH)	0.25
IGNITION CALIBRATION FACTOR	0.68 (INFORMATIONAL ONLY)
MIX ID NUMBER	G10006
MIXING TEMPERATURE	311F
COMPACTION TEMPERATURE	290F

Headquarters:
Construction Engineer------ X
Materials File-----------------X
General File-------------------X
Bituminous Section----------X
Region:
Administrator------------44--X
Materials Eng.-----------44--X
PE: ----R. POLLOCK-------X (2)

T178- 1
T166-
T172-
T175-
T152- 1
T153- 1

REMARKS: VERIFY MIXING AND COMPACTION TEMPERATURE PRIOR TO PRODUCTION RICE VALUE OF 2.318 = 144.3 LBS/FT^3

THOMAS E . BAKER, P.E.
Materials Engineer
By: Dennis M. Duffy P.E. [________]
(360) 709-5420
Date: ____/____/_____

Acceptance Testing for Asphalt Content

Before acceptance testing can occur, an Ignition Furnace Correction Factor (IFCF) has to be established for each furnace to be used. Standard Operating Standard (SOP) 728 is the procedure to accomplish this task.

Exercise 4: Using the IFCF worksheet in the back of the book

Calculate the Ignition Furnace Correction and enter the result on the Ignition Furnace worksheet in box #8 under "Calibration Factor".

Data Given: Pb = 7.4% (found on IFCF bags)

MA 1 = 8.12
MA 2 = 8.04

Sampling Schedules of Lot and Sublot

The Job Mix Formula (JMF) is the ***Lot***. A change or adjustment of percentages in any constituent i.e., gradation or asphalt content, constitutes a new JMF and therefore creates a new ***Lot***.

A new random sampling plan is required for statistical acceptance of each sublot. This requires the start of a new acceptance sample numbering system.

An example would be:

JMF 1 / Acceptance #1 @ 475 tons Total tons to date = 475

After producing 800 tons the Contractor requests from the Project Engineer to increase the percent passing of the #8 sieve and the Project Engineer agrees. This constitutes a new JMF.

The Tester would compute a new random sampling schedule with the remaining tons to be produced.

JMF 2 / Acceptance #1 @ 125 tons Total tons to date = 925

Random Sampling Plan

Exercise 5:

Using the Random Schedule worksheet found in the back of the book and the total proposed quantity of mix for HMA Cl. Superpave 1/2" PG 58-22 at 1133 tons.

1. Determine the type of evaluation, using criteria listed in SS 5-04.3(8)A

    a. Stastistical
    b. Nonstatistical
    c. Commercial

2. Determine sublot size in accordance with SS 5-04.3(8)B

3. Fill in the IFCF using the computed “Correction Factor” from the IFCF worksheet.

4. Use the Random Number Chart to fill in the Random No. beginning with the last two digits of the IFCF, (if the IFCF =1.24, begin @ 24).

5. Compute your Random Sampling Plan

    a. First Test is at ___________________ tons

    b. Last Test is at ___________________ tons

Test Results – Challenge of Acceptance

The Contractor may challenge sublot sample test results. To challenge the test results the Contractor must submit a written challenge within five working days after receipt of the specific test results. A split of the original acceptance sample shall be sent to the Regional Materials Laboratory for testing.

Part 6

Volumetrics

Part 6 Volumetrics

Definitions

The objective of this module is to introduce you to the most common terms and acronyms use in the Superpave Industry. Volumetric analysis of the Hot Mix Asphalt mixture is not a new concept, it has been used in the three major mix design processes; Marshall, Hveem and now Superpave.

Typically there are two or three letter designations to identify the volumetric property.

Each position of the acronym has a significant role.

First position:	**X**xx
Second position:	X**x**x
Third position:	Xx**x**

Generally, the first position will tell you what measurement is being assigned.

Pxx	P = Percent (%) Round to the tenth (0.0)
Gxx	G = Gravity (Specific) Round to the thousandth (0.000)
Vxx	V = Volume Round to the tenth (0.0)

The second position will indicate what type of material is being evaluated. The second and third positions are not capitalized**.**

X**a**x	a = air
X**b**x	b = binder
X**m**x	m = mix
X**s**x	s = stone (aggregate)

The third position will indicate what property of the material is being evaluated

Xx**a**	a = absorbed or apparent
Xx**b**	b = bulk
Xx**e**	e = effective
Xx**m**	m = maximum

When verbalizing the acronym, start with the third position, followed by the first position then the second position.

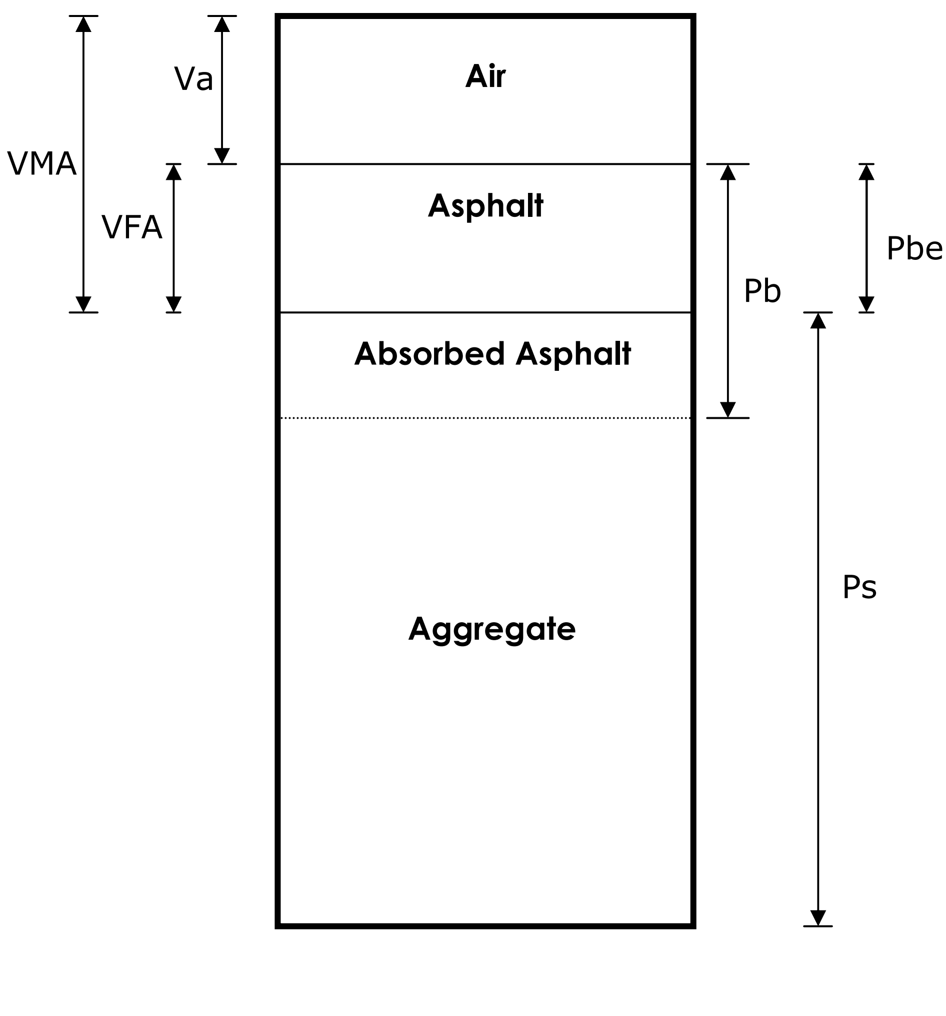
Example:

Gse would be**: Effective, Specific Gravity** of the **Stone**

Complete understanding of these acronyms, will help solve the mystery of the volumetric properties, and better prepare us to evaluate the mix quality.

Asphalt is the glue that holds the aggregates together. Percent Binder (Pb) is the term used in the volumetric analysis to describe asphalt content.

Air is used to make room for thermal expansion of the binder when it expands between the aggregate particles. Graphically depicted in the chart below is a break down of the volumetric nomenclature used for the calculations.



Component diagram of a compacted HMA sample

Relationships

It is helpful for the tester/inspector to have basic knowledge on how each of the mixture components can affect volumetric properties.

There are some unique relationships that can be evaluated in the test results we generate.
When analyzing test data we look at trends rather than individual tests. This will help us determine whether it is the product or testing that is showing inconsistencies in the material.

When studying these relationships, think about which of the Test Methods are being performed to evaluate that volumetric property.

Test Method	**Volumetric Property**
Asphalt Content ↑	Gmb ↑
Asphalt Content ↑	Gmm ↓
Asphalt Content ↑	Va ↓
P200 ↑	Va ↓
P200 ↑	Gmb ↑
P200 ↑	Gmm ↓
Gmm ↑	Gmb ↓

These relationships are only guidelines and tools to use for evaluation of your testing procedures and/or testing equipment.

Exercise 6:

Using the "Information Packet" found in Appendix A, calculate the volumetric properties for this mix using the "Volumetric Worksheets" in Appendix B.

Record your work on the Volumetric Worksheet for SOP 731 found in the "Information Packet".

VOLUMETRIC WORKSHEET
SOP 731

Contract No.	Class Mix	JMF No.	Sample No.	Tester	Date

Volumetrics	Specifications	Test Results
Gmb		
Gmm		
%Gmm @Nini	**>89.0**	
Va (Voids)	**3.0 - 6.0**	
VMA	**>13.0**	
VFA	**65 - 75**	
D/A	**0.6 - 1.6**	

Gyratory Compaction Level	Compaction Height
Nini	
Ndes	

Information	**from Design**
Gb	
Gsb	
Information	**from Ignition Furnace**
AC	
P 200	

Gmb

Bulk Specific Gravity of Compacted Asphalt Mixtures using Saturated Surface-Dry AASHTO T166 (Method A)

$$Gmb = \frac{Mass, Dry}{(Mass, SSD - Mass, Water)}$$

$$Gmb = \frac{\_\_\_\_\_\_\_}{(\_\_\_\_\_\_\_ - \_\_\_\_\_\_\_)}$$

Gmb	=	

Gmm (Rice)

Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures AASHTO T209

$$Gmm = \frac{Mass, Dry}{[(Mass, Dry) + (Mass, Flask, Water) - (Mass, Flask, Sample, Water)]}$$

$$Gmm = \frac{\_\_\_\_\_\_\_}{[(\_\_\_\_\_\_\_) + (\_\_\_\_\_\_\_) - (\_\_\_\_\_\_\_)]}$$

Part 7

Test Procedures

Part 7 Test Procedures

WSDOT 716

Random Sampling for Location of Testing & Sampling Sites

AASHTO T-168

Sampling HMA Mixtures

WSDOT 712

Reducing HMA Mixtures

AASHTO T-40

Sampling HMA Materials

WAQTC TM-6

Determining Moisture Content of HMA

WSDOT SOP 728

Determining the IFCF for HMA

AASHTO T-308

Determining Asphalt Content of HMA

AASHTO T-27/T-11

Sieve Analysis of Fine & Coarse Aggregates

AASHTO T-209

Maximum Specific Gravity of HMA

AASHTO T-312

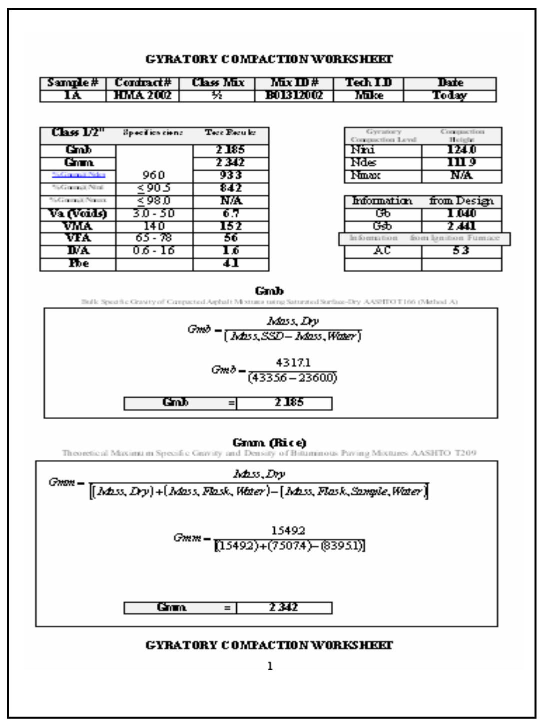
Superpave Gyratory Compactor

AASHTO T-166

Bulk Specific Gravity of Compacted HMA Mixtures

WSDOT SOP-731

Determining Volumetric Properties



GYRATORY COMPACTION WORKSHEET

Sample #	Contract#	Class Mix	Mix ID #	Tech I.D	Date
1A	HMA 2002	½	B01312002	Mike	Today

Class 1/2"	Specifications	Test Results
Gmb		2.185
Gmm		2.342
%Gmm@Ndes	96.0	93.3
%Gmm@Nini	≤ 90.5	84.2
%Gmm@Nmax	≤ 98.0	N/A
Va (Voids)	3.0 - 5.0	6.7
VMA	14.0	15.2
VFA	65 - 78	56
D/A	0.6 - 1.6	1.6
Pbe		4.1

Gyratory Compaction Level	Compaction Height
Nini	124.0
Ndes	111.9
Nmax	N/A

Information	from Design
Gb	1.040
Gsb	2.441
Information	from Ignition Furnace
AC	5.3

Gmb

Bulk Specific Gravity of Compacted Asphalt Mixtures using Saturated Surface-Dry AASHTO T166 (Method A)

$$Gmb = \frac{Mass, Dry}{(Mass, SSD - Mass, Water)}$$

$$Gmb = \frac{4317.1}{(4335.6 - 2360.0)}$$

Gmb	=	2.185

Gmm (Rice)

Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures AASHTO T209

$$Gmm = \frac{Mass, Dry}{[(Mass, Dry) + (Mass, Flask, Water) - (Mass, Flask, Sample, Water)]}$$

$$Gmm = \frac{1549.2}{[(1549.2) + (7507.4) - (8395.1)]}$$

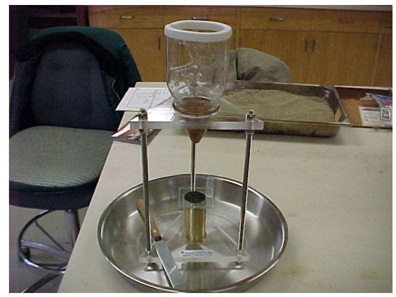
Gmm	=	2.342

GYRATORY COMPACTION WORKSHEET

1

AASHTO T-304

Uncompacted Void Content of Fine Aggregate



ASTM D-4791

Test Method for Flat & Elongated in C.A.

AASHTO T-176

Sand Equivalent Test

Appendix A

Appendix A

Contents

Washington State Department of Transportation - Materials Laboratory
PO Box 47365 Olympia / 1655 S 2nd Ave. Tumwater / WA 98504
BITUMINOUS SECTION TEST REPORT

TEST OF: A.C.P. JOB MIX DESIGN SUPERPAVE CLASS 1/2" WORK ORDER NO: 006020
DATE SAMPLED: 7/11/01 LAB ID NO: 0000195459
DATE RECVD HQS: 7/11/01 TRANSMITTAL NO: 195459
SR NO: 508 MIX ID NO: G10006
SECTION: SR5 TO SR7

---------------CONTRACTOR'S PROPOSAL---------------

Mat'l	3/4"- 1/2"	3/8"-#4	1/4"-0	COMBINED
Source:	L-23	L-23	L-284	
Ratio:	15%	26%	59%	
1"	100.0	100.0	100.0	100
3/4"	100.0	100.0	100.0	100
1/2"	50.1	100.0	100.0	93
3/8"	10.0	89.1	100.0	84
#4	0.0	12.3	93.8	59
#8	0.0	3.4	64.1	39
#16	0.0	3.0	39.5	24
#30	0.0	2.8	25.1	16
#50	0.0	2.7	18.0	11
#100	0.0	2.4	12.7	8
#200	0.5	2.3	8.9	6.0

---------------LABORATORY ANALYSIS---------------SPECIFICATIONS--

ASPH % BY TOTAL WT OF MIX:	7.0	7.4	7.5	
%Gmm @ Ninit: 8	84.6	85.6	85.9	≤ 89.0%
% VOIDS @ Ndes:100	5.6	4.4	4.1	4.5%
% VMA @ Ndes: 100	16.1	15.9	15.9	≥ 14.0%
% VFA @ Ndes: 100	66	73	75	65 - 75
DUST / ASPHALT RATIO	1.2	1.1	1.1	0.6 - 1.6
Pbe- PERCENT BINDER EFFECTIVE	5.1	5.6	5.7	
Gmm - MAX S. G. FROM RICE	2.333	2.318	2.314	
Gmb - BULK S. G. OF MIX	2.202	2.216	2.220	
Gsb - OF AGGREGATE BLEND		2.441		
Gsb - OF FINE AGGREGATE		2.479		
Gb - SPECIFIC GRAVITY OF BINDER		1.040		

---------------LOTTMAN STRIPPING EVALUATION---------------

	0%	1/4%	1/2%	3/4%	1%
Visual Appearance:	NONE	NONE	NONE	NONE	NONE
% Retained Strength:	78	85	98	92	96

---------------RECOMMENDATIONS---------------

SUPPLIER	ALBINA
GRADE	PG64-22
% ASPHALT (BY TOTAL MIX)	7.4
% ANTI STRIP (BY WT ASPH)	0.25
IGNITION CALIBRATION FACTOR	0.68 (INFORMATIONAL ONLY)
MIX ID NUMBER	G10006
MIXING TEMPERATURE	311F
COMPACTION TEMPERATURE	290F

Headquarters:
Construction Engineer------ X
Materials File-----------------X
General File-------------------X
Bituminous Section----------X
Region:
Administrator------------44--X
Materials Eng.-----------44--X
PE: ----R. POLLOCK-------X (2)

T178- 1
T166-
T172-
T175-
T152- 1
T153- 1

REMARKS: VERIFY MIXING AND COMPACTION TEMPERATURE PRIOR TO PRODUCTION RICE VALUE OF 2.318 = 144.3 LBS/FT^3

THOMAS E . BAKER, P.E.
Materials Engineer
By: Dennis M. Duffy P.E. [________]
(360) 709-5420
Date: ____/____/_____

Washington State Department of Transportation

Ignition Furnace Worksheet

Work Order No.	Class Mix	Time	Sample No.	Plant Location	Agg. Source	Date Sampled
6020	1/2 " 64-22	13:25	2	L-23	L-23	Today

Water Content (WAQTC TM-6)

	(1) Initial	After 90 min.	(2) Final		
Time	13:40	15:20	15:50	(3) Mass (Wt.) H_2O (1 - 2)	**0.6**
Mass Weight	1316	1315.5	1315.4		
Tare Weight	549.6	549.6	549.6	(4) Percent H_2O ((3) / (1)) x 100	**0.08**
Sample Weight	**766.4**	765.9	**765.8**		

Ignition Furnace Data (AASHTO T-308)

(5) Mass (Wt.) of Empty Basket(s)	**3039.1**	**(10) Chamber Set Point (^{O}C)**	**538**
(6) Mass (Wt.) of Basket(s) and Sample	**4713.8**	**(11) Calibrated Asphalt Content (Printed Ticket)**	**5.42**
(7) Mass (Wt.) of Sample (Enter in Furnace Controller) (6) - (5) (Enter whole number)	**1674.7**	**(12) Corrected Asphalt Content (11) - (4)** 5.42 - 0.08	**5.34**
(8) Calibration Factor	**0.68**	**(13) Mass (Wt.) of Residual Aggregate (use to calculate gradation)**	**1565.7**
(9) Furnace (Mass) Wt. Reading	**4716.9**	**(14) Mass (Wt.) of dry aggr after wash.** ** Must be within 0.2% of pan wt.	**1478.2**

Aggregate Gradation (AASHTO T-30)

Sieve Size (in.) Record all sieves **Sieve Size**	Accumulative Weight Retained	 **Percent** Retained	**Percent** Passing	JMF	Tolerance	Specifications
3/4	0	0	100	**100**		**99 - 100**
1/2	45.9	3	97	**93**	**90 - 99**	**90 - 100**
3/8	195.4	12	88	**84**	**78 - 90**	
#4	574.2	37	63	**59**	**54 - 64**	
#8	881.9	56	44	**39**	**35 - 43**	**28 - 58**
#16	1116.2	71	29	**24**		
#30	1257.2	80	20	**16**		
#50	1348.5	86	14	**11**		
#100	1419.2	91	9	**8**		
#200	1463.5	93.5	6.5	**6.0**	**4.0 - 7.0**	**2.0 - 7.0**
Pan	1477.6					

Comments

Signature of Contractor's Rep.	Date	Inspector	Date

DOT Form 350-560 Modified 3/2001 Distribution: OSC Materials Lab, Region Materials Lab, Contractor

Contract Number	SR Number	Project Engineer	Mix ID Number	Pit Number	Date
6020	508		G10006	L-23	

Section	Contractor	
SR5 to SR7		☒ English Units ☐ Metric Units

	Jar 1	Jar 2	Sample greater than 1500g.
A = Sample Mass (wt)	[1] 1549.2	[3]	grams
D = Mass (wt) - Pyncometer Jar, Water and Cover	7507.4		grams
E = Mass (wt) - Pycnometer Jar, Sample, Water and Cover	8395.1		grams
T - Water Temperature	77		°F
R - Temperature Correction Factor (From Table 2)	1.00000		
F = Rice Specific Gravity $\frac{A}{A+D-E} \times R$	[2] 2.342	[4]	

Note: When a constant temperature water bath is used to maintain the water temperature at 77°F ± 1 (25° C ± 0.5) the temperature correction "R" should be 1. For all other water temperatures refer to table for the appropriate value for "R".

Rice Specific Gravity (Weighted Average)

$$\frac{([1] \times [2] + [3] \times [4])}{([1] + [3])} \quad \frac{([\underline{1549.2} \times \underline{2.342}] + [\underline{\quad\quad} \times \underline{\quad\quad}])}{(\underline{1549.2} + \underline{\quad\quad})} = \underline{2.342}$$

Note: Calculate the Rice Specific Gravity "F" to 3 decimal places.

Rice Density (*English Units*) $F \times 62.24$ lb/ft³ $\underline{2.342} \times 62.24$ lb/ft³ = $\underline{145.8}$ lb/ft³

Rice Density (*Metric Units*) $F \times 997$ kg/m³ $\underline{2.342} \times 997$ kg/m³ = $\underline{2335}$ kg/m³

Note: Calculate the Rice Density in Metric Units to the nearest whole number.
Calculate the Rice Density in English Units to the nearest 0.1 lb/ft³.

Average Rice Density Determination

The average of the five (5) most recent Rice Densities from a given JMF should be used for compaction control.

If less than 5 Rice Densities are available, the averages will be based on the number of Rice Densities available, excluding mix design data. See test procedure for additional information.

	Test Date	Rice Density	
(1)			lb/ft³
(2)			lb/ft³
(3)			lb/ft³
(4)			lb/ft³
(5)			lb/ft³
	Running Average		lb/ft³

Note: Metric - Round to whole number. English - Round to 0.1 lb/ft³.

Tested By	Date

DOT Form 350-157 EF
Revised 4/2002

Distribution: Copies to Project Engineer; Region Materials

Gyratory Compactor

Sample ID: 2   Time: 16:55   Date: Today

Serial Number: 636
Pressure: 600 Kpa

	1	2	3	4	5	6	7	8	9	10
0	132.9	130.9	129.1	127.5	126.5	125.5	124.6	124.0	123.3	122.7
10	122.3	121.7	121.3	120.9	120.6	120.3	119.9	119.6	119.3	119.1
20	118.8	118.6	118.3	118.1	117.9	117.7	117.7	117.4	117.2	117.0
30	116.9	116.7	116.6	116.4	116.3	116.1	116.0	115.9	115.7	115.6
40	115.5	115.4	115.3	115.2	115.1	115.0	114.9	114.7	114.7	114.6
50	114.5	114.5	114.4	114.3	114.2	114.1	114.1	114.0	113.9	113.9
60	113.8	113.7	113.7	113.6	113.5	113.5	113.4	113.3	113.3	113.2
70	113.2	113.1	113.1	113.0	113.0	112.9	112.9	112.9	112.8	112.7
80	112.7	112.6	112.6	112.6	112.5	112.5	112.4	112.4	112.3	112.3
90	112.3	112.2	112.2	112.2	112.1	112.1	112.0	112.0	112.0	111.9

Appendix B

Appendix B

Contents

VOLUMETRIC WORKSHEET
SOP 731

Contract No.	Class Mix	JMF No.	Sample No.	Tester	Date
6020	1/2" 64-22	2	10	Dat be U	Today

Specifications		
Gmb		
Gmm		
%Gmm @ Nini	$\leq$ 89.0	
Va (Voids)	2.5 – 5.5	
VMA	> 13.0	
VFA	65 - 75	
D/A	0.6 - 1.6	

Gyratory Compaction Level	Compaction Height
Nini	
Ndes	

Information from Design	
Gb	
Gsb	
Information from Ignition Furnace	
AC (Pb)	
P 200	

Gmb

Bulk Specific Gravity of Compacted Asphalt Mixtures using Saturated Surface-Dry AASHTO T166 (Method A)

$$Gmb = \frac{Mass, Dry}{(Mass, SSD - Mass, Water)}$$

$$Gmb = \frac{4317.1}{(4335.6 - 2360.0)}$$

Gmb =	

Gmm (Rice)

Theoretical Maximum Specific Gravity and Density of Bituminous Paving Mixtures AASHTO T209

$$Gmm = \frac{Mass, Dry}{[(Mass, Dry) + (Mass, Flask, Water) - (Mass, Flask, Sample, Water)]}$$

$$Gmm = \frac{\_\_\_\_\_\_\_}{[(\_\_\_\_\_\_\_) + (\_\_\_\_\_\_\_) - (\_\_\_\_\_\_\_)]}$$

Gmm =	

VOLUMETRIC WORKSHEET

% Gmm at Ndesign

$$\%Gmm@\ Ndes = \frac{Gmb}{Gmm} * 100 \qquad \%Gmm@\ Ndes = \frac{\_\_\_\_\_\_\_\_}{\_\_\_\_\_\_\_\_} * 100$$

%Gmm@Ndes =	

%Gmm@Nini

$$\%Gmm\ @\ Nini = 100 * \left(\frac{Gmb * Hdes}{Gmm * Hini}\right) \qquad \%Gmm\ @\ Nini = 100 * \left(\frac{\_\_\_\_\_\_}{\_\_\_\_\_\_} * \frac{\_\_\_\_\_\_}{\_\_\_\_\_\_}\right)$$

%Gmm@Nini =	

Air Voids (Va)

$$Va = 100 * \left[1 - \left(\frac{Gmb}{Gmm}\right)\right] \qquad Va = 100 * \left[1 - \left(\frac{\_\_\_\_\_\_}{\_\_\_\_\_\_}\right)\right]$$

Va =	

Voids in Mineral Aggregate (VMA)

$$VMA = 100 * \left[1 - \frac{Gmb * \left(\frac{100 - Pb}{100}\right)}{Gsb}\right]$$

$$VMA = 100 * \left[1 - \frac{\_\_\_\_\_\_ * \left(\frac{100 - \_\_\_\_\_\_}{100}\right)}{\_\_\_\_\_\_}\right]$$

VMA =	

VOLUMETRIC WORKSHEET

Voids Filled with Asphalt (VFA)

$$VFA = 100 * \left[\frac{(VMA - Va)}{VMA}\right] \qquad VFA = 100 * \left[\frac{(\_\_\_\_\_\_\_ - \_\_\_\_\_\_\_)}{\_\_\_\_\_\_\_}\right]$$

VFA =	

Gravity Stone Effective (Gse)

$$Gse = \frac{100 - Pb}{\left(\frac{100}{Gmm} - \frac{Pb}{Gb}\right)} \qquad Gse = \frac{100 - \_\_\_\_\_\_\_}{\left(\frac{100}{\_\_\_\_\_\_\_} - \frac{\_\_\_\_\_\_\_}{\_\_\_\_\_\_\_}\right)}$$

Gse =	

Percent Binder Effective (Pbe)

$$Pbe = -(Ps * Gb)\left(\frac{Gse - Gsb}{Gse * Gsb}\right) + Pb$$

$$Pbe = -(\_\_\_\_\_\_ * \_\_\_\_\_\_\_) * \left(\frac{\_\_\_\_\_\_\_ - \_\_\_\_\_\_\_}{\_\_\_\_\_\_\_ * \_\_\_\_\_\_\_}\right) + \_\_\_\_\_\_\_$$

Pbe =	

Dust to Asphalt Ratio

$$D / A = \frac{\text{\% Passing \#200 sieve}}{Pbe} \qquad D / A = \frac{\_\_\_\_\_\_\_}{\_\_\_\_\_\_\_}$$

D/A =	